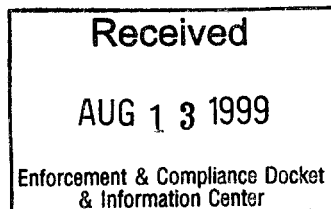


Request for Environmental Project Funds
(Under HDD Settlement)

9 pg

United States vs. Caterpillar, Inc., Civil Action
No. 98-2544 (HHK), D.J. Ref. 905-2-1-2255

"Secondary Pumping System for Emissions and
Temperature Control of Diesel Engines"



1/11/99



ENGINEERED MACHINED PRODUCTS, INC.

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Escanaba, MI 49829
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Current Industry Problem

Today's engines, both diesel and spark ignition, use a single conventional coolant pump for maintaining engine temperature below the established maximums. The drive mechanism for conventional pumps, a pulley or gear, is linked directly to the crankshaft and is therefore not controllable. This direct linkage means that the rate of coolant flow produced by the pump is in direct relation to the engine RPM. However, the cooling requirements of the engine are not a function of engine RPM only, but are affected by vehicle velocity, ambient temperature, engine loading and several other factors. This can result in flow rates greater or sometimes less than required to cool the engine, wasting energy and potentially decreasing engine life. Excess flow can also over-cool the engine causing combustion to occur at less than optimal temperatures, which can negatively impact both fuel economy and emissions.

Although this type of system has been accepted as satisfactory for decades, new emissions standards (requiring substantial reductions in NOx emission levels) mandated in the recent Consent Decree between the EPA and the Diesel Industry will demand increased performance from the coolant system. Exhaust gas recirculation (EGR), which diverts a percentage of exhaust gas to the intake for recombustion, represents a viable option to meet these standards, and is being actively explored by the Diesel Industry. Although EGR produces significant improvements in NOx reduction, it creates potentially insurmountable challenges to designers of conventional cooling systems. Flow rates required for a typical over-the-road (OTR) engine will increase from an average of 90 gpm to as high as 130 gpm to sufficiently cool the EGR gas and maintain a satisfactory air to fuel ratio. It will be difficult and expensive for the Diesel Industry to redesign conventional pumps to handle these significantly increased flow requirements. Current space limitations and conventionally available drive options such as gears and pulleys may make it economically unfeasible to simply redesign today's conventional pumps.

Even if manufacturers are successful in increasing flow capacity from conventional pumps, they will have difficulty optimizing EGR gas temperature since conventional pumps are not controllable. This lack of thermal control could negatively affect fuel economy and possibly cause overheating problems, making it necessary to increase radiator size to account for extreme operating conditions when flow rate is restricted by low RPM, but thermal demand is increased due to high ambient temperatures. The following are additional potential problems of using a conventional, non-controllable, water pump to support EGR cooling requirements:

- Actual flow rate required for all operating conditions is still not known and conventional pumps cannot be adjusted if initial estimates prove to be wrong;
- Flow from conventional pumps to the EGR heat exchanger will be dependent on engine RPM only, causing potential violations of emission requirements under certain conditions;
- Conventional pumps cannot compensate for fouling of heat exchanger, jeopardizing EGR cooling capacity after prolonged use;
- Increased size of pump components (for additional flow) will eliminate ability to economically retrofit existing engines.

Industry Solution: EMP Advanced Secondary Pumping System

EMP has successfully completed bench testing on an advanced secondary coolant delivery system for which the drive mechanism is totally independent of engine RPM. This electronic pump generates a controlled flow rate by utilizing sophisticated computer control logic, which is inherent to the type of motor selected. This "smart pump" will allow for precise control of coolant flow and thus could be used to accurately control both engine temperature and EGR gas temperature. By maintaining the correct EGR temperature, regardless of engine rpm, the NOx levels and fuel economy can be simultaneously optimized. As an additional benefit, the coolant, which has been used to cool the EGR gas, can be diverted back to the engine for faster warm up of the engine and can also be utilized to supplement the main coolant system during extreme thermal conditions.

The advanced pump relies on a non-traditional impeller and diffuser, eliminating the need for the currently required volute, and offering many mounting options. This flow-thru design can be easily adapted to any engine (including retrofits) which is not currently possible, as discussed earlier.

Potential Industry Savings & Benefits

The primary benefits of a secondary pump are the ability to control EGR performance under extreme operating conditions, introduction of engine thermal regulation, and reduction of white smoke under cold start conditions. Additional anticipated benefits are as follows:

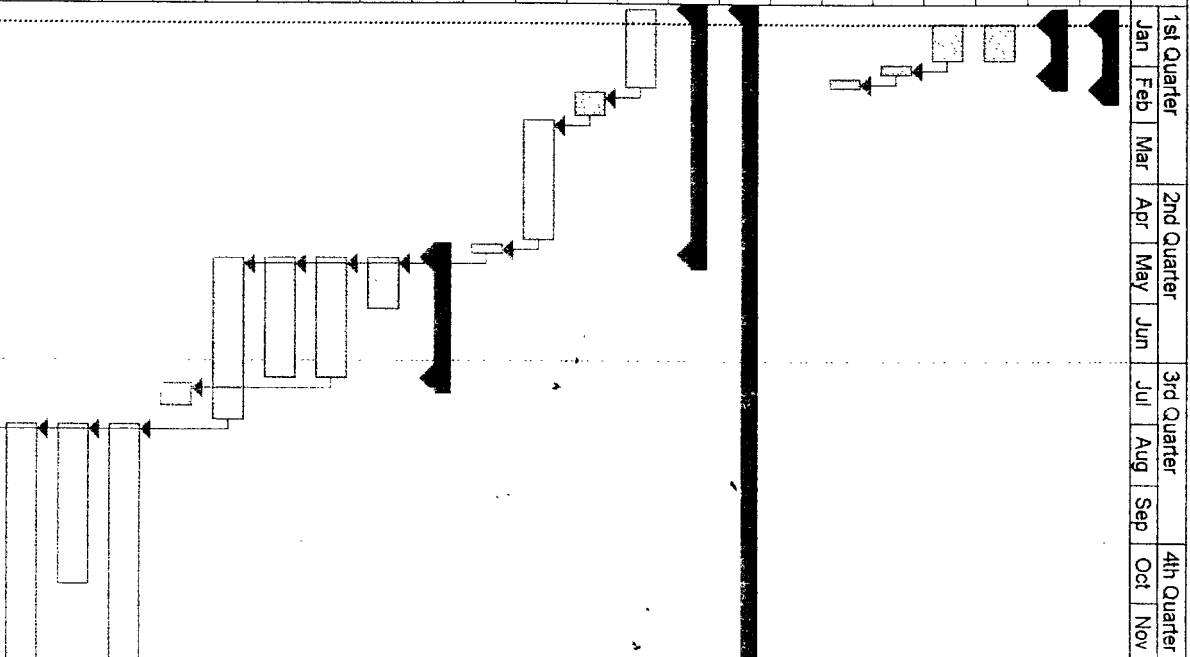
- Could be used to economically retrofit existing engines with EGR cooling
- Less energy draw necessary to achieve additional cooling needs
- No coolant leakage due to elimination of mechanical seal
- May Eliminate need for increases in radiator size which could affect the vehicle aerodynamics
- Mounting location not limited by linkage to engine drive
- Can cool engine after engine shutdown to decrease wear
- Could compensate for fouling of heat exchanger through coolant flow control

Future Advanced Pump Development

Development and testing requirements for the advanced secondary pump are outlined on the attached Gantt chart. Future development work for the next generation coolant delivery systems will include precision thermal management development and a study of the advantages of economically pre-heating engine coolant prior to start-up. The estimated costs for the above development phases are outlined below:

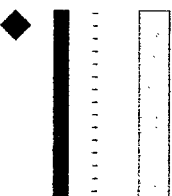
Phase 1	- Development of Secondary Coolant Pump	\$3,650,000
Phase 2	- Development of Precision Thermal Management	\$1,400,000
Phase 3	- Study on Pre-Heating Coolant Prior to Start-Up	\$ 500,000

ID	Task Name	Duration	Start	Finish	1st Quarter			2nd Quarter			3rd Quarter			4th Quarter				
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov			
1	Administration	25 days	Mon 1/11/99	Fri 2/12/99														
2	Proposal Efforts	20 days	Mon 1/11/99	Fri 2/5/99														
3	Industry	15 days	Mon 1/11/99	Fri 1/29/99														
4	Government	15 days	Mon 1/11/99	Fri 1/29/99														
5	Final Proposal	5 days	Mon 2/1/99	Fri 2/5/99														
6	Finalize Project Plan	5 days	Mon 2/8/99	Fri 2/12/99														
7																		
8	Secondary Pump Development	250 days	Mon 1/4/99	Fri 12/17/99														
9	Initial Prototype Build/Tests	90 days	Mon 1/4/99	Fri 5/7/99														
10	In-house Build/ Tests	30 days	Mon 1/4/99	Fri 2/12/99														
11	Motor Specification Test	10 days	Mon 2/15/99	Fri 2/26/99														
12	Engine Tests	45 days	Mon 3/1/99	Fri 4/30/99														
13	Update Design	5 days	Mon 5/3/99	Fri 5/7/99														
14	Next Phase Prototypes	45 days	Mon 5/10/99	Fri 7/9/99														
15	Mechanical Components	20 days	Mon 5/10/99	Fri 6/4/99														
16	Motor	45 days	Mon 5/10/99	Fri 7/9/99														
17	Controller	45 days	Mon 5/10/99	Fri 7/9/99														
18	Build Bench Reliability Testers	60 days	Mon 5/10/99	Fri 7/30/99														
19	Update Performance Tests	10 days	Mon 7/12/99	Fri 7/23/99														
20	Accelerated Reliability Tests	90 days	Mon 8/2/99	Fri 12/3/99														
21	Dynamometer Tests	60 days	Mon 8/2/99	Fri 10/22/99														
22	Field Tests	100 days	Mon 8/2/99	Fri 12/17/99														

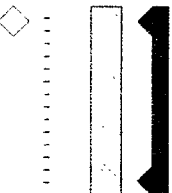


Project SECPUMPEGR
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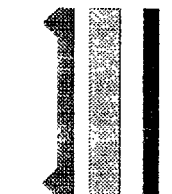
Task
Split
Progress
Milestone



Summary
Rolled Up Task
Rolled Up Split
Rolled Up Milestone



Rolled Up Progress
External Tasks
Project Summary



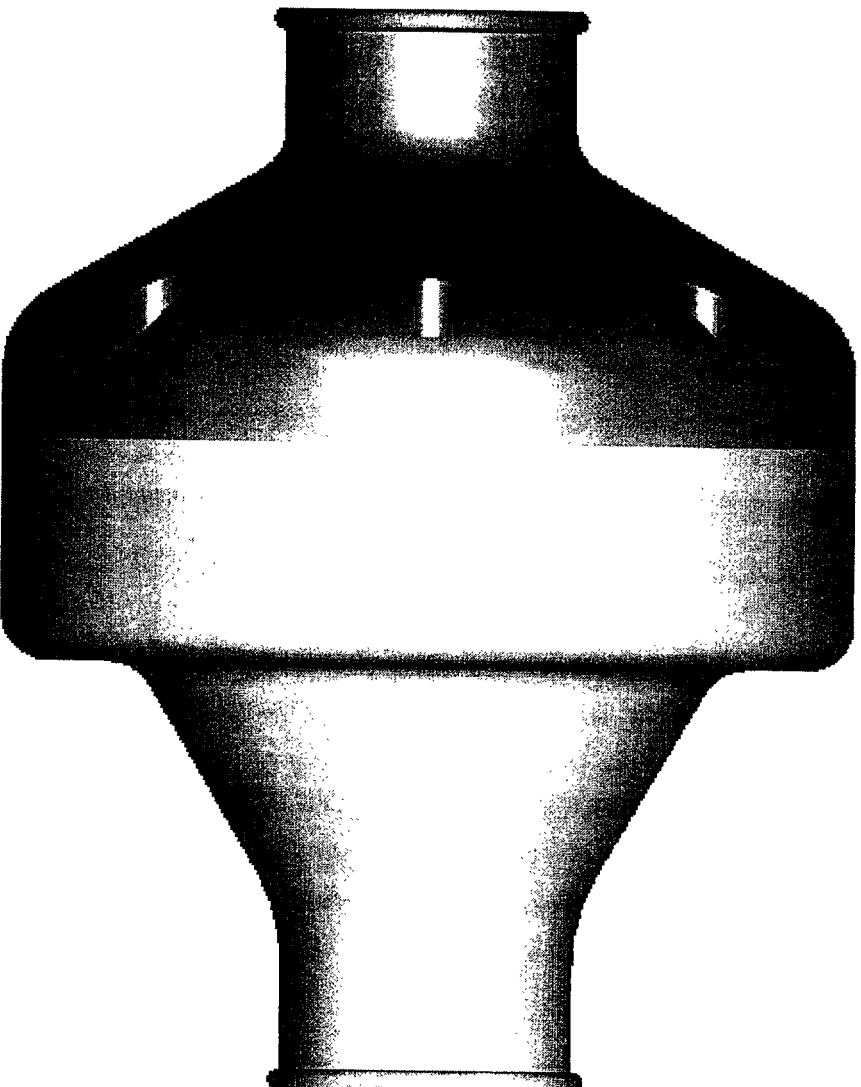
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Project: SECPUMPEGR
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Split	<input type="text"/>	Rolled Up Task	<input type="text"/>	External Tasks	<input type="text"/>
Progress	<input type="text"/>	Rolled Up Split	<input type="text"/>	Project Summary	<input type="text"/>
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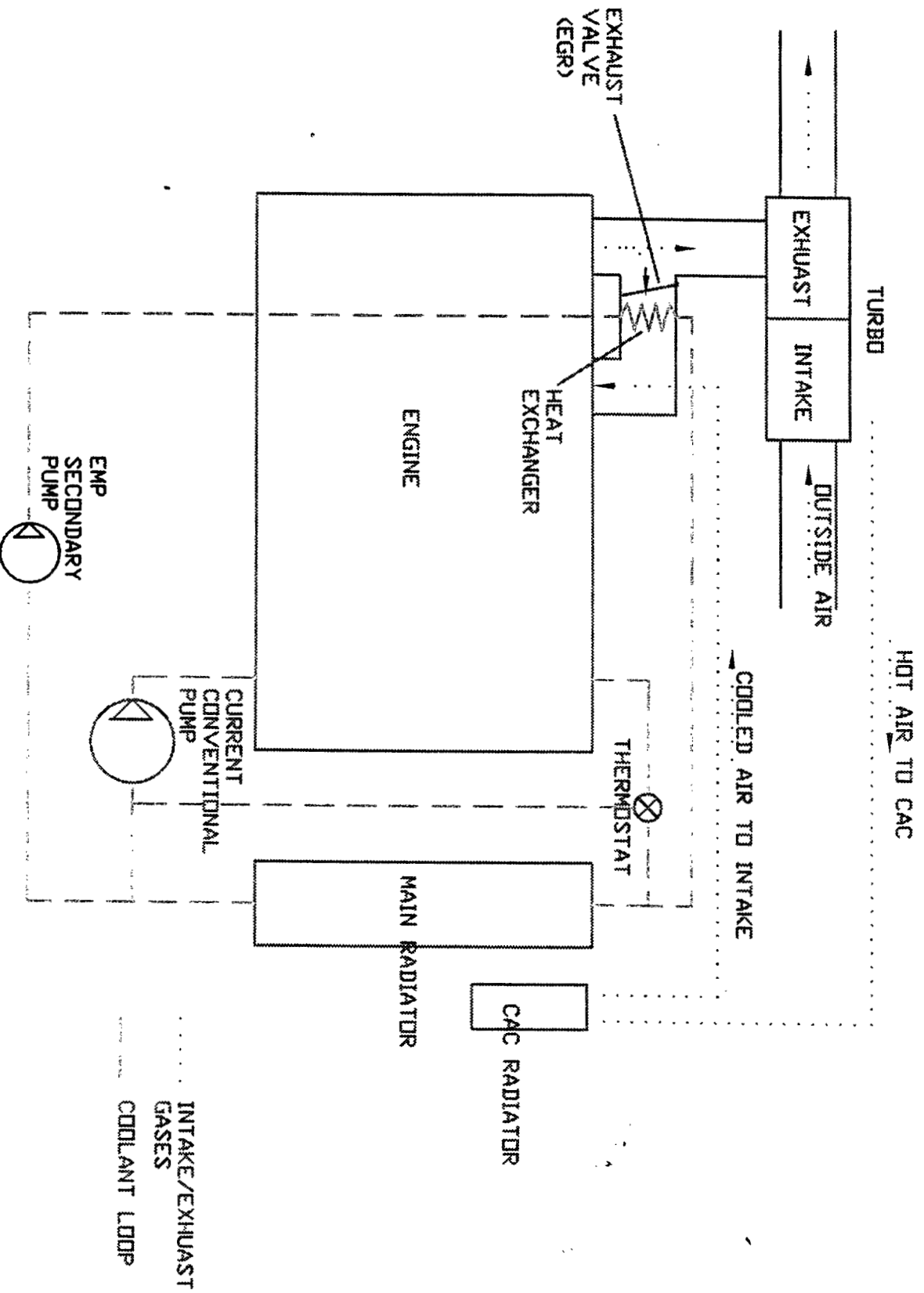
Secondary Pump for EGR and Engine Temperature Control



Actual Size for 50 GPM Pump

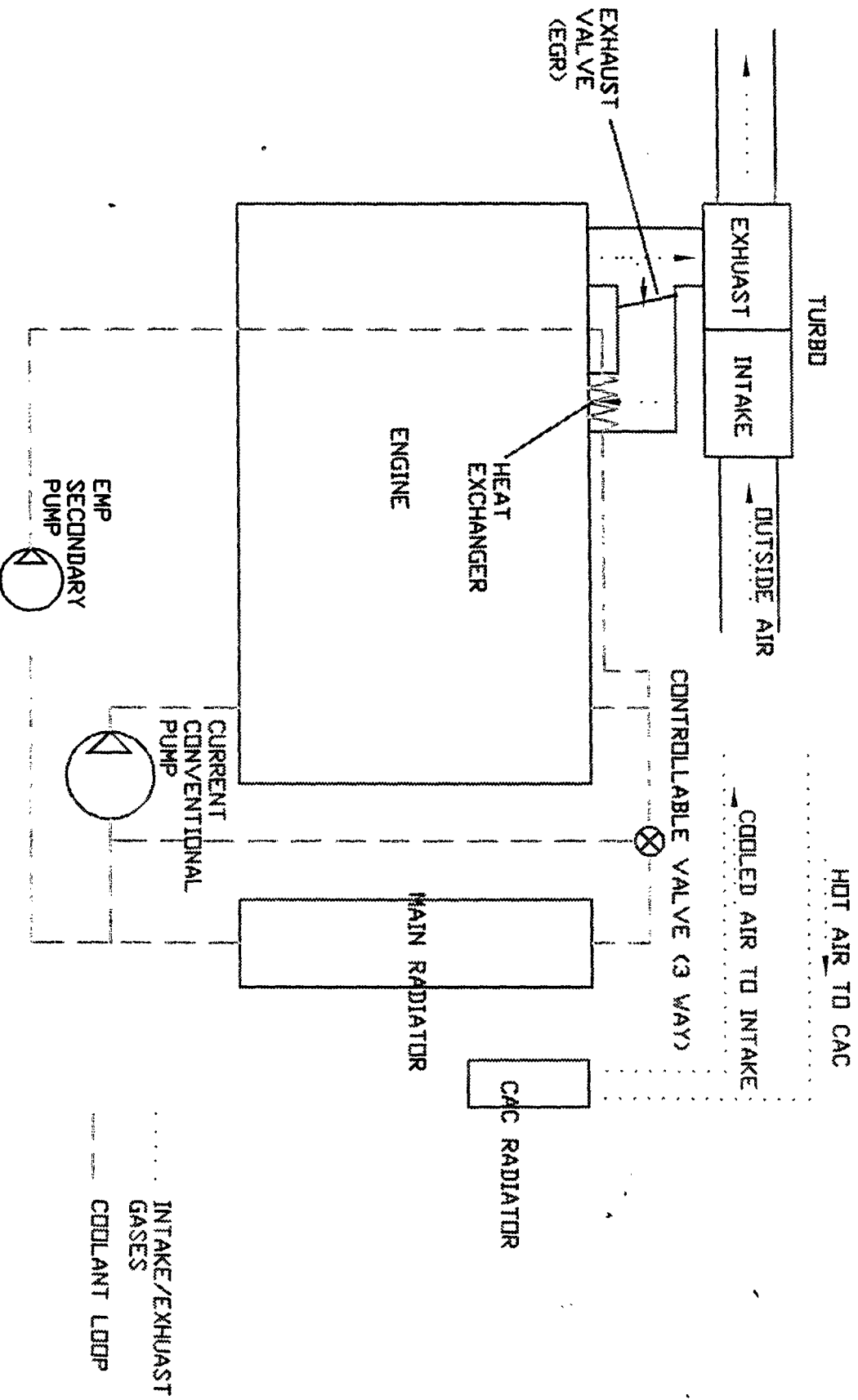
Engineered Machined Products

ENGINEERED MACHINED PRODUCTS SECONDARY PUMP FOR EGR COOLING



ENGINEERED MACHINED PRODUCTS

SECONDARY PUMP FOR EGR COOLING & THERMAL REGULATION



ENGINEERED MACHINED PRODUCTS

SECONDARY PUMP FOR EGR COOLING & ADVANCED THERMAL REGULATION

